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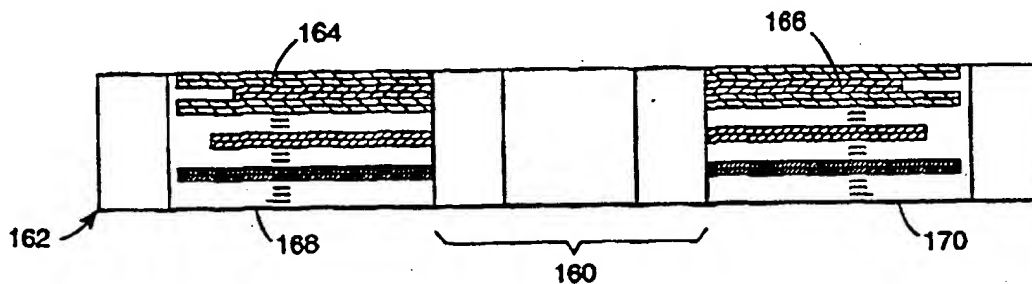


INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : G11B 20/12, 5/008, 27/32, 23/42		A1	(11) International Publication Number: WO 95/34892
			(43) International Publication Date: 21 December 1995 (21.12.95)
(21) International Application Number: PCT/US95/07303			(81) Designated States: CN, JP, KR, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).
(22) International Filing Date: 8 June 1995 (08.06.95)			
(30) Priority Data: 08/259,200 13 June 1994 (13.06.94) US			
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Published
With international search report.

(54) Title: DIRECT FILE ACCESS SYSTEM AND REDUCED REWIND DATA CONFIGURATION FOR MAGNETIC TAPE



(57) Abstract

A direct file access system for a magnetic tape where all data files begin at a designated location on the tape. The direct file access system may be used with a reduced rewind data configuration to decrease data access time. The reduced rewind data configuration divides data files into generally equal portions so that data files begin and end at the designated location on the tape, eliminating rewind sequences.

Serial No. 09/577,637
Docket No. 249212013300

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DIRECT FILE ACCESS SYSTEM AND REDUCED REWIND DATA
CONFIGURATION FOR MAGNETIC TAPE

Background of the Invention

5

Field of the Invention

The present invention relates to a direct file access system for a magnetic tape and to a system for reducing the number of tape retensioning passes. The present invention also relates to a reduced rewind data configuration on a magnetic tape, which may be used in combination with the direct file access system and the system for reducing the number of tape retensioning passes.

Description of the Related Art

Conventional tape organization is sequential, with records/files recorded serially along the length of the tape. Files typically are recorded on a single track from the Beginning of Tape (BOT) to the End of Tape (EOT). If the file is longer than the length of the tape, the tape drive steps the head to a different track and the recording process continues back from the EOT toward the beginning. Consequently, the multiple tracks on the tape are accessed in a serpentine manner so as to appear as one long tape to the tape drive.

Advanced tape organization systems place a directory of a few kilobytes at the BOT which allows the read/write head to be moved laterally across the tape to the desired track. The tape then is advanced in a high-speed ballistic manner to the approximate location of the beginning of the desired record.

However, even with optimum organization and search algorithms such as Quick File Access (QFA), the average access to an individual record may be anywhere from ten seconds to several minutes. A sequential search can take anywhere from ten minutes to hours.

Access time is becoming an even greater problem as tapes get longer. For example, based on 1/3 of the length of the tape access, a 365 m tape has an average access time of 40 seconds at 3.0 m/s. It is projected that the tape length in new 5.25 form factor tape cartridges with 6.3 mm tape will increase to between 460 and 550 m in the near future, further increasing access time.

Another factor that slows access to data is the automatic refresh or retensioning procedures employed every time the cartridge is loaded into the drive. This procedure causes the entire tape to be wound and rewound. At worst, this results in a 2-4 minute delay for long tapes. Additionally, if a tape is shuffled repeatedly in a short region, or if its temperature varies greatly since it was last used, the tape can lose tension to a degree that will degrade data integrity, requiring additional time consuming retensioning procedures.

In order to take full advantage of the huge data capacity available on tape cartridges, a direct file access system, a system for reducing the number of retensioning passes, and a reduced rewind data configuration for magnetic tapes is needed to reduce the average access time, preferably to less than 2 seconds.

Summary of the Invention

The present invention is directed to a direct file access system for magnetic tape. One or more service regions are established in a middle portion of the longitudinal length of the tape. Data storage areas having a plurality of data tracks extending longitudinally along the tape are defined on either side of each such service region. Data files are written to the storage areas such that the data files all begin adjacent to a service region.

Brief Description of the Drawings

Fig. 1 is a schematic illustration of an exemplary tape drive containing a magnetic tape cartridge;

Fig. 2 is a schematic illustration of a first embodiment of the direct
5 file access for magnetic tapes;

Fig. 3 is a schematic illustration of an alternate embodiment in which multiple service regions are arranged longitudinally along the tape;

Fig. 4 is a schematic illustration of a preferred embodiment of the reduced rewind data configuration in which all data files begin and end at
10 the BOT area;

Fig. 5 is an alternate embodiment of the reduced rewind data configuration in which data files are divided into two portions so that all data files begin and end at the BOT area; and

Fig. 6 is a schematic illustration of a magnetic tape utilizing the
15 preferred direct file access system in combination with the reduced rewind data configuration.

Detailed Description of the Preferred Embodiments

Fig. 1 is a perspective view of an exemplary tape drive 10. The
20 tape drive 10 may perform either single channel or multi-channel recording, in which multiple channels are recorded simultaneously (in parallel) on tape 18. A frame 12 receives a double-reel cartridge 14. The tape drive 10 includes a conventional cartridge loading mechanism 16 which receives the cartridge 14, opens a tape cover (not shown) to expose
25 tape 18, and positions the tape 18 for recording and playback. The loading mechanism 16 preferably engages a reference datum (not shown) on the cartridge 14 to align the tape 18 with a read/write head assembly
30.

The tape 18 is driven longitudinally past a read/write location 22 by
30 a motor 24 engaged with capstan roller 20. As the tape 18 advances

through the read/write location 22, data is recorded ("written") or read ("played back") from the tape by means of the read/write head assembly 30. A sensor 32 is located between the read/write head assembly 30 and the frame 12 to measure the tension of the tape 18. Alternatively, the sensor may engage the tape 18 directly or in combination with a support member.

Although Fig. 1 illustrates a belt-driven reel-to-reel cartridge, it will be understood that the present invention is not limited by the type of cartridge or the tape drive. For example, a direct drive reel-to-reel or single reel cartridge may utilize the present invention. It will also be understood that the above described tape drive 10 and cartridge 14 are for illustration purposes only, and in no way limit the scope of the present invention.

Fig. 2 is a schematic illustration of a preferred embodiment of the direct file access system 50 for magnetic tapes 52. A service region 54 is defined on the tape 52. First and second storage regions 56, 58 are defined adjacent to the service region 54. The service region 54 preferably includes a file directory 60 identifying the files located in the first and second data storage regions 56, 58. The service region 54 also includes at least one parking zone 62 in which no data is recorded, for parking the magnetic heads (not shown) on the tape 52. In the preferred embodiment a parking zone 62 is provided on both sides of the file directory 60 as a method of reducing the number of back hitches necessary to acquire servo tracks 78 when going in the direction opposite the orientation of the file directory 60.

In the preferred embodiment, magnetic markers 64 demarcate a Beginning of Tape (BOT) region 74 and an End of Tape (EOT) region 76 from the data storage regions 56, 58. The magnetic markers 64 also demarcate the parking zones 62, the file directory 60, and the other edge of the data storage regions 56, 58. Retensioning tracks 66 and/or 68 may

be included in the service region 54 and/or in the data storage areas 56, 58.

The service region 54 may comprise 3 to 6 m of magnetic tape 52. When the tape 52 is stopped, the read/write heads (not shown) preferably are located in the parking zone 62 with one read channel roughly aligned with the file directory 60. When the tape 52 begins operational movement, the tape drive 10 performs the appropriate acquisition of servo track 78 in the parking zone 62 and reads the file directory 60 for the location of the record to be written or read. The read/write heads (not shown) then are moved to the appropriate track to begin either reading or writing the desired file.

Each data storage region 56, 58 has a plurality of data tracks 70, 72 which extend longitudinally along the length of the tape 52. All data files 80, 82 begin adjacent to the service region 54. For purposes of this application, a data file may contain one or more data records. If a file contains more than one record, the records preferably are written and read sequentially along the length of the magnetic tape. For long data files, it is possible to write a portion in each data storage region 56, 58, as will be discussed below.

For example, data file 90 begins at location 92 adjacent to the service region 54 and extends away therefrom, traversing a serpentine path in the data storage area 58. Since the file 90 is longer than the data track, the read/write heads merely turn around at the EOT 76 and continue recording the file 90 on an unused track. Data file 90 ends at location 94. In the preferred embodiment, the remainder of the file 90 is written to an adjacent track, although this is not required. In marked contrast to conventional file organizations, the next file also starts at the service region 54, not the end 94 of the file 90. Therefore, the tape 52 must be rewound to the service region 54 after the reading/writing of the file 90 is completed.

Data file 96 begins adjacent to the service region 54 and extends toward the BOT 74. Since the data file 96 is shorter than a complete track in data storage area 56, the tape 52 will need to be advanced to the service region 54 after the data file 96 is written/read.

5 On a tape drive having 144 tracks, the present direct file access tape system 50 utilizing service region 54 provides access to 288 files with an average access time of less than 2 seconds. A drive with 216 records would result in 432 direct access files utilizing the present direct file access for tape systems 50.

10 The tensioning track 68 is evaluated while the tape is being returned to the service region 54, or tensioning track 66 is evaluated once the read/write heads are returned to the service region 54, to determine if tape retensioning is necessary (as discussed further below), and the read/write heads are aligned with the file directory 60. The file directory 60
15 is then updated and the read/write heads are stopped in the parking zone 62. It will be understood that only one parking zone may be needed and that all operations may be initiated from that zone.

As discussed above, access time to data is increased due to automatic refresh or retensioning procedures. A retensioning cycle
20 typically includes advancing the tape to the EOT and then rewinding to the BOT. A retensioning cycle preferably occurs every time a cartridge is loaded into a tape drive or when a predetermined number of tape tension reducing events have occurred. Tape tension reducing events include for example: the tape has been shuffled repeatedly along a short region of the
25 tape (greater than 50 passes over a fixed region and less than the full tape length) or the temperature of the tape has changed by more than 16° C.

As illustrated in Fig. 1, the first embodiment of the system for reducing the number of retensioning passes includes a force transducer 32 proximate the read/write heads 30 of the tape drive 10 to monitor tape

tension. If tape tension drops below a predetermined level, a retensioning pass is initiated.

In an alternate embodiment, a worst case data pattern, located on the retensioning tracks 66 and 68 in Fig. 2, may be written to the tape 52 in an area of normally lower tape tension. The retensioning tracks 66, 68 preferably are written to the track farthest from the reference datum (not shown) of the tape cartridge 14. The worst case data pattern is a pattern that is sensitive to increased head-to-tape separation due to loss of tape tension. The worst case data pattern is intended to produce the worst case amount of peak shift that is sensitive to signal loss. For example, the retensioning tracks 66, 68 may include a combination of "dibits" or "tribits" as exemplified by -0011000111000- where each "one" is a bit or flux reversal written on the tape.

Upon loading the cartridge 14 into the drive 10, the drive reads the retensioning tracks 66, 68 and compares the actual error rate to the expected error rate for that track. If the actual error rate is significantly greater than the expected error rate, a retensioning pass may be initiated.

Alternatively, the drive may read the retensioning tracks 66, 68 at fixed intervals to determine whether a retensioning sequence is required. In the preferred embodiment, the worst case data patterns 66, 68 are written to the upper track at the BOT or EOT, and/or the top track in the service region.

In yet another embodiment, the tape drive initiates a retensioning pass after a specified number of tape tension reducing events has occurred. For example, if the tape 52 has been shuffled repeatedly over a short segment a retensioning pass may be initiated.

Data files may also be arranged so that the full length of the tape 52 is traversed, causing the tape to be refreshed or retensioned. Data file 84 fills two complete tracks in the first data storage area 56, beginning at location 85 and ending at location 86. The remainder of data file 84 is

written to tracks 87, 88 in the second data storage area 58. Consequently, reading or writing data file 84 automatically refreshes or retensions the tape 52.

Fig. 3 illustrates an alternative fast file access for tape systems in which three service regions 54a, 54b, 54c are provided at fixed intervals along the length of the tape 52. In this configuration, six data storage areas 56a, 58a, 56b, 58b, 56c, 58c are arranged along the length of the tape 52. Directory information and data are stored in each service region 54a-c and data storage areas 56a-c, 58a-c, respectively, in much the same fashion as in the previously described embodiment.

It will be understood by those skilled in the art that more than three service regions may be provided in some circumstances. For example, if numerous records of known length are to be stored on the tape 52, service regions can be arranged to create a plurality of data storage areas which approximate the size of the data files. In a tape configuration utilizing more than one service region, the tape 52 may be advanced to the service region adjacent to the desired record in a ballistic manner. However, in the preferred embodiment, only a single service region is provided on each tape in order to maintain the 2 second access time.

Figs. 4 and 5 illustrate reduced rewind data configurations which may be used with the fast direct file access for tape systems discussed above. In particular, the data configurations of Figs. 4 and 5 are designed to eliminate the rewind sequence after reading or writing a data file.

Fig. 4 illustrates a first embodiment of a reduced rewind data configuration 100 in which data records are concatenated within a file so that all files start and end at the BOT area. Data file 101 illustrates two records 102, 104 of generally equal length. In the preferred embodiment, a magnetic marker 103 is placed at the end of the record 102 so that the tape drive knows to change tracks to read/write the second record 104 in the file 101.

Data file 106 contains three records 108, 110 and 112. Since file 108 is slightly longer than the combined length of files 110 and 112, there is a short period of rewind between the end of file 108 and the beginning of file 110. Again, magnetic markers may be provided at the end of each
5 record along the length of the data file 106.

Data file 114 includes two records 116 and 118. The record 116 is longer than the data track. When the read/write head reaches the EOT (end of tape) area 120, the tape head (not shown) moves laterally across the tape to an empty data track and the remainder of the record 116 is
10 written on another data track extending back towards the BOT area 122. In the preferred embodiment, the rest of the record 116 is written on the adjacent data track. The record 118 is appended to record 116 and extends the full distance back to the BOT 122 area. A remainder 124 of the record 118 is then divided into two generally equal portions and written
15 on two data tracks so that the read/write heads terminate the write sequence at the BOT 122. In the preferred embodiment, the remainder 124 of record 118 is divided in half so that no rewind time is required. As discussed above, a significant portion of the tracks containing the remainder 124 are unused blank tape, highlighting the trade-off between
20 the present reduced rewind data configuration and maximizing tape utilization.

Data file 126 illustrates an example of a file comprising a single large record. The file 126 begins at the BOT 122 and is written in conventional serpentine fashion out to the EOT area and back to the BOT
25 area again. The remainder 128 is then divided into two generally equal portions and written on two preferably adjacent tracks so that the read/write heads terminate the write sequence at the BOT 122.

Fig. 5 is an alternate embodiment of the reduced rewind data configuration 130 of the present invention wherein the length of a data file

is determined prior to writing it to the tape so that all files begin and end at the BOT 132 area.

Data file 134 is small enough to reside on two tracks of a data storage area 140. The data file 134 is divided into two generally equal portions 136, 139. The first portion 136 is written starting from the BOT area 132. The second portion 139 is written on a preferably adjacent track starting proximate at the end of the first portion 136 and extending back to the BOT 132. A magnetic marker 142 preferably is included at the end of the first portion 136 so that the tape drive recognizes that the remainder of the file 132 is written on a different track.

Data file 144 is larger than two data tracks. The file 144 is evaluated to determine the even number of whole data tracks 146, 148 required and the size of the remainder portion 150. The even number of data tracks 146, 148 are written to the tape and the remainder portion 150 is divided into two generally equal portions which are written on two separate tracks. Consequently, the data file 144 begins and ends at the BOT 132.

While it will be recognized that the reduced rewind data configurations illustrated in Figs. 4 and 5 do not maximize tape utilization, the reduced access time achieved by eliminating the rewind sequence can be significant. As the cost of magnetic tape continues to decline, utilizing 50% or less of the tape capacity becomes less of a problem. Additionally, with future generations of tape cartridges capable of containing tens to hundreds of gigabytes of information, utilizing only 50% of the cartridge capacity is not critical. Finally, as new tape drives become available which can access multiple tapes, the present reduced rewind data configuration makes a huge amount of data storage capacity available with an extremely small access time. It also will be recognized that this design may require more cooperation between the tape drive and the associated computer. For maximum efficiency the computer should tell the tape drive the total

size of the file before sending a file to the drive so that the drive can determine when to stop writing a file on one track and start on the next. Alternatively, but less efficiently, the drive can write the file using the fast direct file access system for tapes illustrated in Fig. 2, determine the size of the resulting file, then re-write the file according to the reduced rewind data configuration for tapes illustrated in Figs. 4 and 5.

Fig. 6 illustrates an embodiment which combines the fast direct file access system for tapes illustrated in Fig. 2 with the reduced rewind data configuration for tapes illustrated in Figs. 4 and 5. In this embodiment, a service region 160 is provided proximate the center of the tape 162. Data files 164, 166 then are written in the two data storage areas 168, 170 defined on the tape using the reduced rewind data configurations discussed above.

Fig. 6 show two "BOT" and "EOT" regions on the tape. These are not the physical beginning of tape and end of tape, but are logical positions. With these logical dividers, the drive can read from/write to the tape going in either direction as if it were reading/writing from the beginning of a tape to the end of a tape. This allows use of much the same control systems and algorithms as used with conventional tape formats.

The embodiment illustrated in Fig. 6 is particularly useful for storing records of a known maximum length, such as X-rays. Since the individual files may be shorter than the length of the tape, one or more service regions can be placed along the length of the tape to create a plurality of data storage regions which correspond to the size of the X-rays (see Fig. 3). Table 1 illustrates the length of tape required to store several typical types of records and their corresponding densities in kilobits per inch (kbpi), or kilobytes per centimeter (kB/cm):

TABLE 1

Record Lengths for Several Bit Densities

5

	HDTV (920x1960)	Std. X-ray	Chest X-ray	Large Color Picture
Size (MB)	5.53	10	20	100
Density	Length in m/folded as in Figs. 4&5			
12.5 kbp 3.97 kB/cm	89.3/44.7	162/81	325/163	162/81
67.7 kbp 21.5 kB/cm	16.5/8.2	29.9/14.9	60.0/30.0	300/150
100 kbp 31.7 kB/cm	11.3/5.6	20.4/10.2	40.5/20.3	203/102
150.0 kbp 47.6 kB/cm	7.3/3.7	13.4/6.7	27.1/13.6	135/67.7

While all of the above embodiments have been described with files, markers, services regions and the like ending at precise locations, one of skill in the art will understand that a small buffer zone usually should be provided between regions on the tape, at the ends of files and the like to allow for variability in the tape, tape drive, temperature, humidity and the like. Particularly when determining how to divide a file between tracks so that it ends back at the service region, such a buffer zone should be included in the calculation.

15 It should be understood that the exemplary embodiments illustrated above in no way limit the scope of the invention. Other modifications of

the invention will be apparent to those skilled in the art in view of the foregoing descriptions. These descriptions are intended to provide specific examples of embodiments which clearly disclose the present invention. Accordingly, the invention is not limited to the described
5 embodiments or to the use of specific elements, dimensions, materials or configurations contained therein. All alternative modifications and variations of the present invention which fall within the spirit and broad scope of the appended claims are covered.

We claim:

1. A direct file access system for a magnetic tape, comprising:
a magnetic tape having a beginning area, an ending area, and a center area arranged longitudinally along the tape;
5 at least one service region on the tape proximate the center area;
first and second data storage areas for storing data files on the tape, the first data storage area having a plurality of data tracks extending longitudinally along the tape between the service region and the beginning area, the second data storage area having a plurality of data tracks
10 extending longitudinally along the tape between the service region and the ending area; and
a plurality of data files in the first and second storage areas, all data files in the first and second storage areas beginning adjacent to the service region.
15
2. The direct file access system of claim 1, further comprising:
a tape drive having read/write heads proximate a read/write location for reading and writing data on the magnetic tape and means for advancing the magnetic tape past the read/write location;
20 data storage means in the tape drive for reading and writing data files in the first and second storage areas.
3. The direct file access system of claims 1 or 2 wherein the magnetic tape comprises more than one such service region spaced along
25 the tape designating multiple such data storage areas.
4. The direct file access system of any of claims 1-3 wherein the data files are separated into first and second portions, the first portion being written on a first data track in a direction extending away from the
30 service region, the first portion having an ending location, and the second

portion being written on a second data track beginning proximate the ending location of the first portion and extending toward the service region.

5. The direct file access system of any of claims 1-4 wherein
5 the data file is divided into a primary portion requiring an even number of data tracks and a remainder portion, the primary portion being written on the magnetic tape to an even number of data tracks starting adjacent to the service region and ending adjacent to the service region, and the remainder portion being separated into first and second portions, the first
10 portion being written on a data track beginning adjacent to the service region in a direction extending away from the service region and the second portion of the data file being written on another data track ending adjacent to the service region.

15 6. The direct file access system of any of claims 1-5 wherein the magnetic tape includes a file directory located in a service region for identifying data files located in the first and second data storage areas.

7. The direct file access system of any of claims 1-6 wherein
20 each service region includes a parking zone for locating the read/write heads when the tape is not being advanced past the read/write location.

8. The direct file access system of any of claims 1-7 wherein the magnetic tape further includes magnetic markers adjacent to the first and
25 second data storage areas.

9. The direct file access system of any of claims 2-8 wherein the tape drive includes means for monitoring the number of tape tension reducing events and for initiating a retensioning cycle if a predetermined
30 number of tape tension reducing events has occurred.

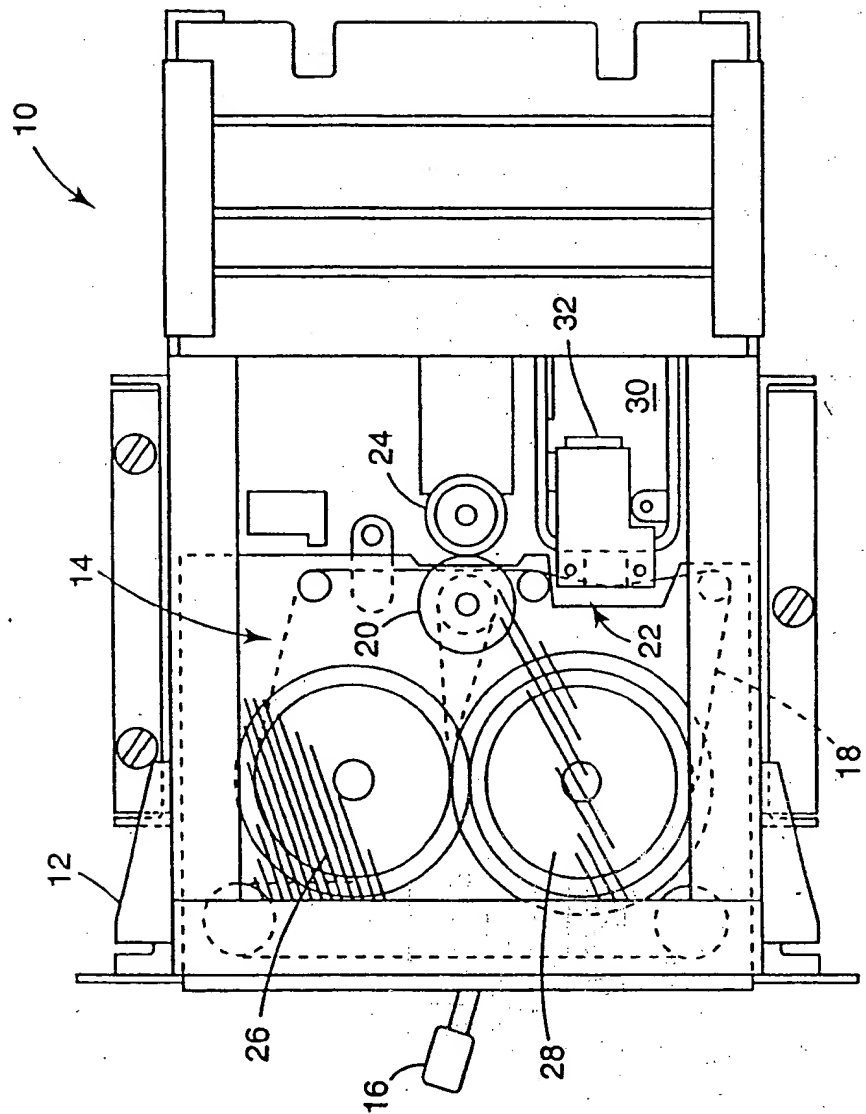


FIG. 1

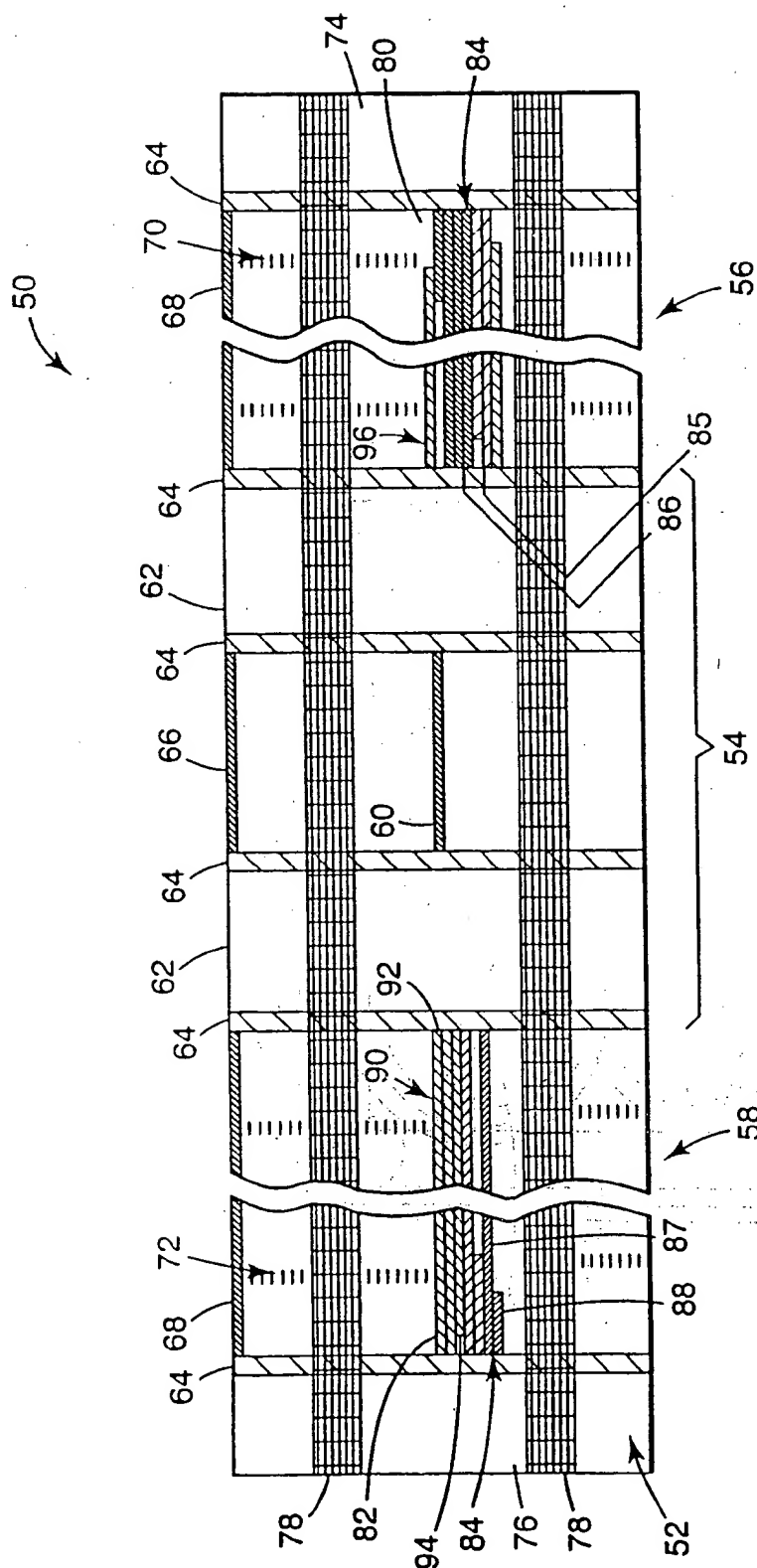


FIG. 2

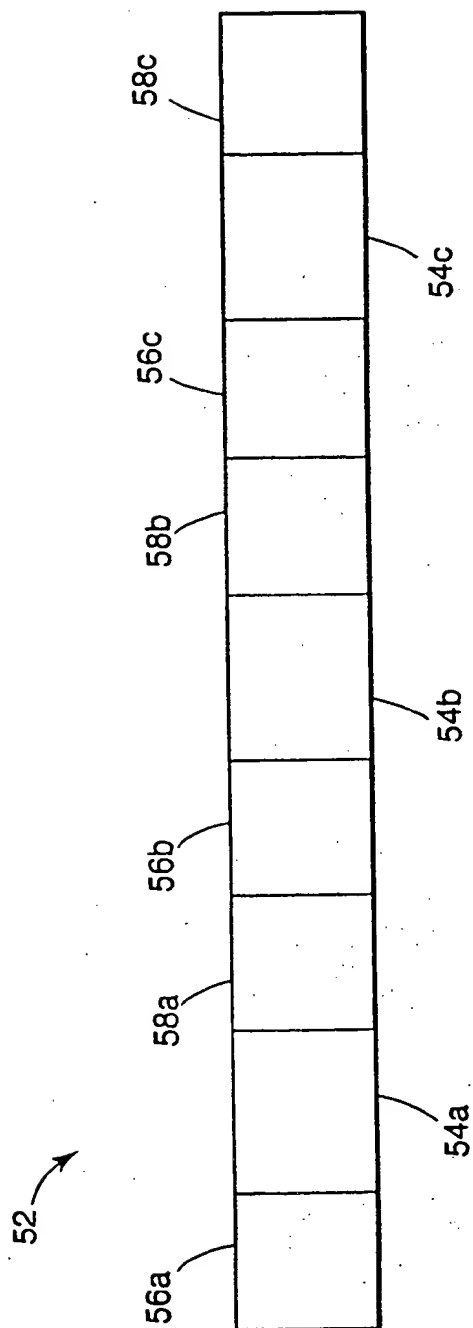


FIG. 3

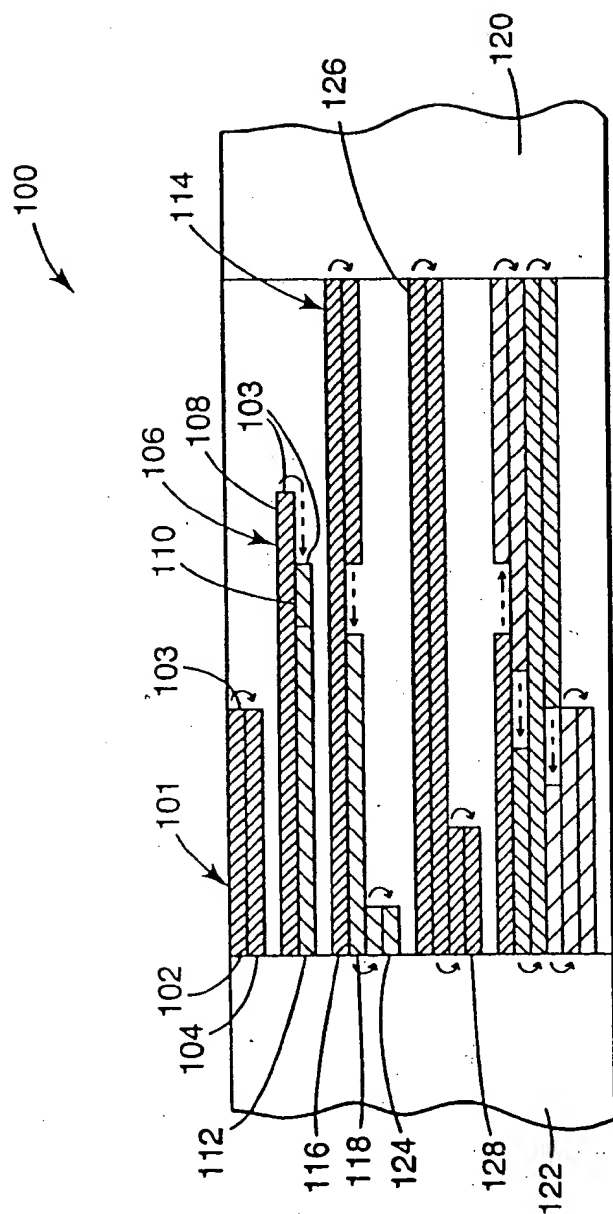


FIG. 4

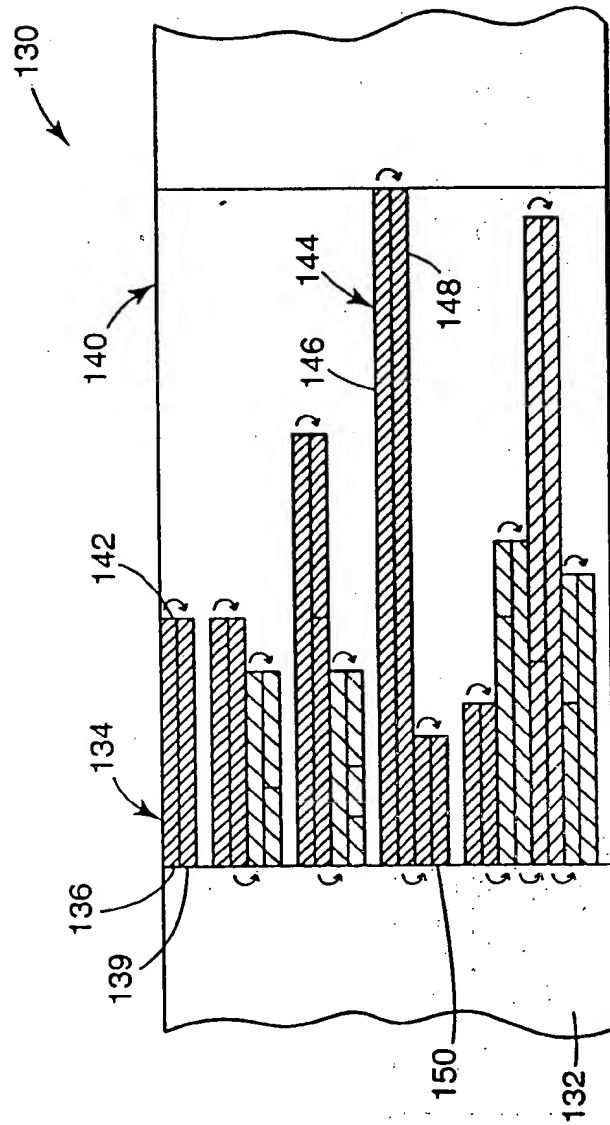


FIG. 5

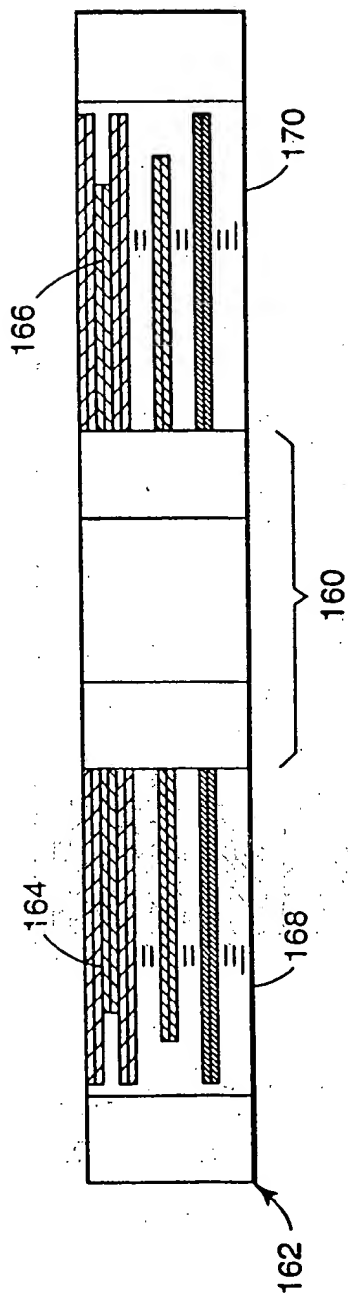


FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 95/07303

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 G11B20/12 G11B5/008 G11B27/32 G11B23/42

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 G11B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,4 498 107 (YOSHIMARU TOMOHISA ET AL) 5 February 1985 see column 2, line 52 - column 3, line 30 see figure 4	1,2
A	WO,A,93 17420 (AMPEX SYSTEMS CORP) 2 September 1993 see page 19, line 22 - line 29 see claims 1-5; figure 5	1-3
A	WO,A,93 17422 (AMPEX SYSTEMS CORP) 2 September 1993 see claims 1-3; figure 5	1-3,8

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

18 September 1995

Date of mailing of the international search report

28.09.95

Name and mailing address of the ISA

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 95/07303

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